Psychoacoustic Parameters as a Tool for Subjective Assessment in Catering Premises

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Abstract

Psycho-acoustic perception of an environment is an important factor in the assessment and subjective description of the soundscape. It determines the environmental impact on each of the individuals. The parameters associated with these models allow us to determine ratings of nuisance in each environment in order to make comparisons.

In this paper, a description of various parameters of sound quality (loudness, sharpness, roughness, fluctuation strength and tonality) is made to assess the nuisance / pleasure models by Zwicker. A comparison with different kinds of restaurants is also made. The models involved are influenced by the acoustics of the premises.

Keywords

Building Acoustics; Psycho-acoustic Parameters; Sound Quality; Sound Field

Introduction

The section on noise abatement in the Spanish technical building code (DB-HR-CTE) requires the compliance of certain acoustic parameters. In addition, this norm offers a range of options regarding the possible architectural solutions for the design process to ensure a proper compliance of the requirements.

This norm regulates the requirements for acoustic conditioning and comfort of all premises devoted to public activities, such as restaurants, hospitals, halls for public use, etc. These measures are important because the amount of premises involved in leisure activities and services is quite huge in Spain, so, they have to be effective. In the services sector, catering premises are highlighted. Actually, in Spain, due to the European crisis, a reduction in the number of these premises involved in catering services has been produced. However, there are still more than 280000 bars and restaurants in Spain [1].

The former norm (NBE-CA-88) only stated as mandatory isolation levels for neighbour noise, which could generate nuisance to adjoin premises or houses and vice-versa. With the new rules, all new premises for public use are intended to be acoustically conditioned and soundproofed, in this way people who are in the place will enjoy a sound quality comfort. However, the DB-HR-CTE [2] lacks proposals in acoustic conditioning of this type of premises and it only shows the values of insulation for façades, walls and floors, and some restrictions on the reverberation time. This way, the present wording of this document is not very accurate in details and specification of the comfort conditions pursued. This shortage is also extended to those premises which are not required to meet the demands as they were built prior to the approval of this norm. However, the norm seeks to adapt the rooms or directly improve their acoustic conditioning.

Generally, premises dedicated to catering present a series of acoustic problems according to different considerations such as: the type of noise or the characteristics of the premises. In general, without taking into consideration specific architectural features of the rooms, premises oriented to catering services often have, in a greater or lesser extent, all three existing types of noise:

- Impact noise: is produced by the internal activity in these areas, which causes a high impact noise produced by dragging chairs, footsteps, knocks at the bar, falling objects, etc.
- Airborne noise: is caused by the conversation among the guests. This kind of noise will be over all other sounds –except for the background of music or television, if present.
- Vibrations: the use of necessary elements to ensure the minimum demands in comfort and

hygiene in the room, such as the smoke extractor, cold rooms, air conditioning, etc., cause noise as vibrations that are propagated by the structural elements of the building.

Other studies have selected SPL in order to check the speech interference [3] on relation to the absorption surface. Also in [4] the speech intelligibility from simulations is analysed in dining spaces and cocktail parties.

In this paper, a study of the objective characteristics in several premises will be explained. Also a study of several psychoacoustic parameters is performed with several recordings in each premise. This will help to analyse and make conclusions about the acoustic comfort generated in these facilities from the application of the model of nuisance/pleasantness by Zwicker [5].

Methodology and Materials

For this study, the main indoor acoustic feature (according to DB-HR-CTE) in 6 bars and restaurants has been measured. Here, we also have recorded the soundscape in all the premises, in order to extract psychoacoustic information from these recordings. This psychoacoustic information is related to loudness, sharpness, roughness, and tonality and fluctuation strength.

Description of premises

The six premises include several bars and restaurants in the university and other sites outside.

1) ***Tony's (pizza)***

This is a medium size premise with an area of 117.1 m^2 and a volume of 388.8 m^3, mainly devoted to serving drinks and meals. The room is disposed as in Fig. 1a and there is a terrace with sunshades on the outside. It can accommodate 60 people inside. This bar is in the University.

2) ***Agora (cafeteria)***

It is a premise with an area of 250.5 m^2 and a volume of 758.9 m^3, dedicated to selling drinks and meals. The room is disposed as in Fig. 1b, with a small terrace on the outside. The interior part can hold up to 120 people. This premise is also inside the University.

3) ***Malvarosa (restaurant-cafeteria)***

This place has an area of 216.7 m^2 and a volume 652.2 m^3, devoted to serve menu meals and cafeteria service. The room is arranged as in Fig. 1c with a covered terrace on the outside. The inside part can hold up to 100 people. This restaurant is in the University.

4) ***Trinquet (restaurant-cafeteria)***

Its area is 395.4 m^2 and the volume is 1853.4 m^3. This site is dedicated to making menu meals and to giving cafeteria service. The room is arranged as Fig. 1d with a small terrace on the outside. The interior can hold about 200 people. This restaurant is also inside the University.

5) ***Pizza place in Gandia***

The dining room has a floor area of 69.0 m^2 and a volume of 176.0 m^3. The main commitment of this site is catering of Italian cuisine. The room is arranged as Fig. 1e. There are 33 tables and 66 chairs inside the room.

6) ***Mediterranean restaurant***

The part devoted to customers has a usable area of 120.0 m^2 and a volume of 350.0 m^3. The main use is catering and author cuisine. The maximum capacity inside this premise is 70 people and the inside is arranged as Fig. 1f.

Soundscape recordings for psychoacoustic analysis

For the sound recordings, which afterwards will be used for a psychoacoustic analysis, we have used a digital recorder EDIROL R-09 [6], with 2 microphones. The recordings were made at the center and sides of each cafeteria approximately, to obtain a representative measures.

From these recordings of the soundscape inside the premises and calculating a series of psychoacoustic parameters (loudness, roughness, sharpness, tonality and fluctuation strength), we can establish a comparative criterion for the indoor environmental sound quality of this type of premises from the computation of the nuisance/pleasantness model in each indoor site. This calculation has been performed using the software by Head Acoustics, ARTEMIS [8]. This is a piece of software for recording, analysis and playback, developed to carry out tasks in the field of acoustics and vibration quickly and efficiently.

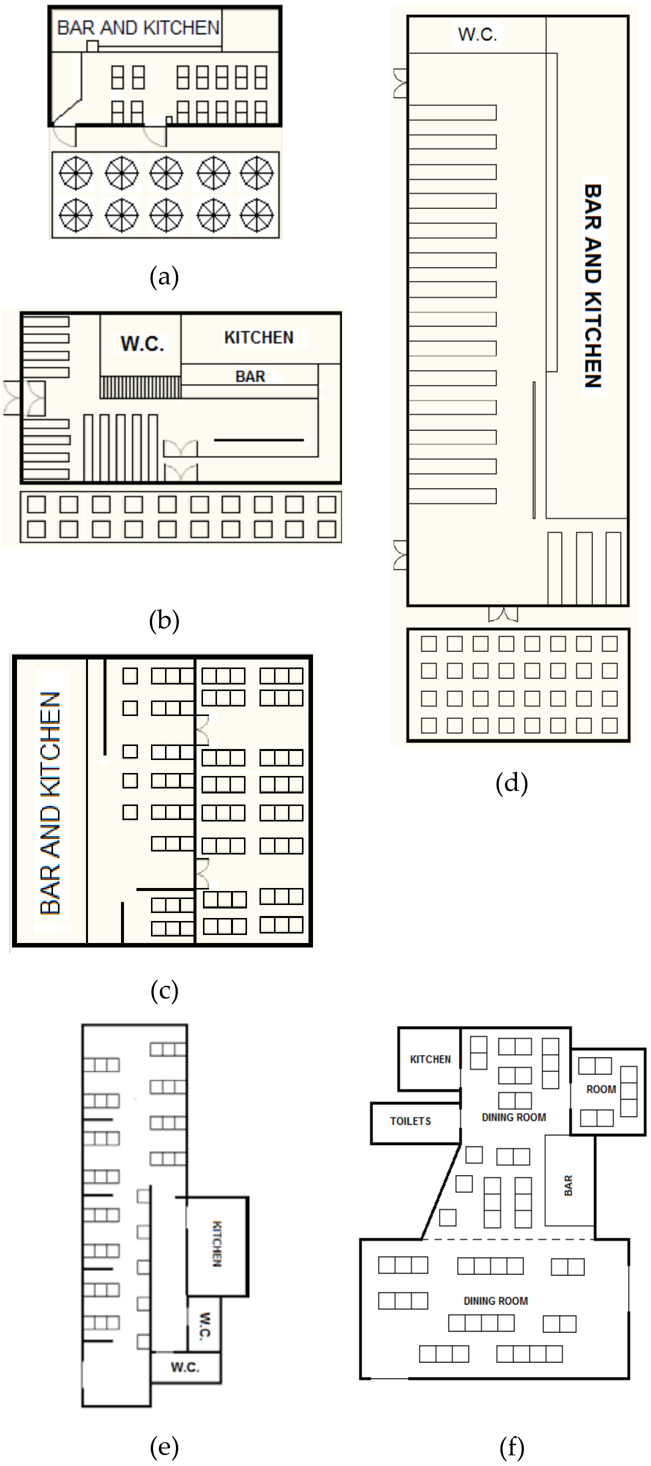


Fig. 1 PLANS IN 4 OF THE STUDIED PREMISES: (A) TONY'S, (B) AGORA, (C) MALVAROSA, (D) TRINQUET, (E) PIZZA PLACE AND (F) MEDITERRANEAN RESTAURANT

1) *Loudness*

The loudness is the value of the human perception of sound volume. This parameter allows understanding the human sensation of volume on linear scale. The loudness unit is the *sone* (derived from the Latin word "sonare"). This unit is established by definition as a sinusoidal tone of frequency 1 kHz with a level of 40 dB. The loudness scale is characterized by the fact that a tone perceived with doubled loudness on the loudness scale, is denoted as twice the value in sone. The loudness of simple tones and complex sounds in auditory tests is determined by comparing the loudness with a 1 kHz sinusoidal tone. The determination of the loudness for stationary signals is specified in ISO 532 B [5][8].

2) *Roughness*

Roughness is a value used in the subjective assessment of sound impressions and also in sound design. With a higher roughness, noise emissions are perceived to be more perceptible and usually more aggressive and annoying, even if for example, the loudness or sound pressure level with A-filter remains unchanged. 'Asper' is the basic unit for roughness.

The impression of roughness occurs whenever there is a time variable envelopment in a critical band, for example, when tones are showing a temporal structure due to a variation in amplitude or frequency. If these changes occur very slowly (below 10 Hz), the human ear is able to capture the changes occurring in a pulsing impression or beat. Increasing the frequency of variation, other sound impressions can be perceived, like "R-roughness" (about 20 Hz). This kind of roughness changes the impression of actual roughness, where the ear is not able to locate the particular temporal changes. The sound with envelopment variations between 20 and 300 Hz is perceived as harsh. Above these frequencies, the main spectral line and pure tones sidebands of modulated amplitude are audible as individual tones. Roughness depends on the central frequency, modulation frequency and modulation depth. The signal level has only a minor influence on the impression of roughness.

By increasing the modulation depth, the impression of roughness is stronger. Dependence on the modulation frequency has a band-pass characteristic, i.e. the impression of roughness decreases strongly to very high or very low frequencies. This impression is maximized at a modulation frequency around 70 Hz. [8].

3) *Sharpness*

Sharpness is a value of sensation that is caused by high frequency components in a given noise. The unit for sharpness is "acum" (from the Latin word

acum which means sharp). The sharpness also outlines the human feeling linearly. The value of one *acum* is attributed to a narrow band noise at 1 kHz with a bandwidth less than 150 Hz and a level of 60 dB. This psychoacoustic parameter is very important because of its influence on the unpleasantness of sounds. [5] [8].

4) Tonality

The tonality of a sound indicates if the sound contains tonal components or broadband noise. The contribution of tones to the tonality depends on its frequency. At about 700 Hz, the impression of maximum tonality is achieved. The narrow band noise with a bandwidth less than 1 Bark, also is perceived as tonal, although in a decreasing degree when the bandwidth is increasing. The unit for tonality, *tu* (tonal unity), is defined for a 1 kHz sine tone with a level of 60 dB. [5][8].

5) Fluctuation strength

The impression called *fluctuation strength* is given by the signal variations with very low modulation frequencies. The maximum for this psychoacoustic quantity is at modulations frequencies around 4 Hz. The unit, named '*vacil*', is defined by the same sinusoidal tone as in the case of roughness, but the modulation frequency is 4 Hz instead of 70 Hz. [5][8].

Psychoacoustic models

A key element in these basic perceptual attributes is that their modelling allows an objective quantification, or equivalently that the subjective value of the attribute could be quantified from the physical characteristics of the signal. Therefore, we have calculated the time variation of the parameters specified in section B and have applied the Zwicker model [5] for nuisance/pleasantness (N/P) to the recordings obtained in each one of the premises.

The corresponding formulas are:

$$P = e^{-0.7\cdot R} \cdot e^{-1.08\cdot S} \cdot (1.24 - e^{-2.43\cdot T}) \cdot e^{(-0.023\cdot L)^2} \quad (1)$$

$$N = \mathrm{L} \cdot (1 + \sqrt{\mathrm{w}_{\mathrm{S}}^2 + \mathrm{w}_{\mathrm{FR}}^2}), \quad (2)$$

where:

$$\mathrm{w}_{\mathrm{FR}} = \frac{2.18}{\mathrm{L}^{0.4}} \cdot (0.4 \cdot \mathrm{F} + 0.6 \cdot \mathrm{R}) \text{ and}$$

$$\mathrm{w}_{\mathrm{FR}} = (\mathrm{S} - 1.75) \cdot 0.75 \cdot \log(\mathrm{L} + 10)$$

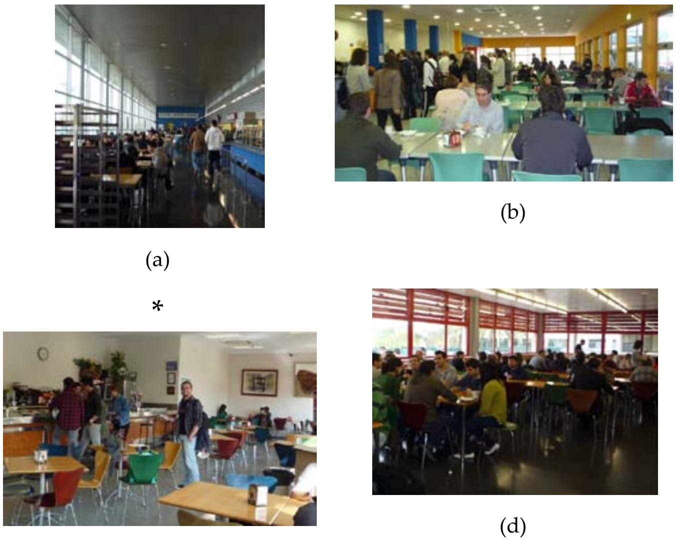
In these formulas the associated values are: Sharpness (S), Roughness (R), Fluctuation Strength (F), Loudness (L) and Tonality (T).

Results and Discussion

In order to determine the relationship between the psychoacoustic model proposed by Zwicker and the acoustic conditions of the premises, we have measured the average reverberation time (T30) from indoor measurements of impulse responses by using MLS signal [9] and the AURORA 4.3 software [10] in each site. Then we have calculated RT_{mid}.

TABLE I T30 AND RT_{MID} FOR EACH PREMISE

	125	250	500	1000	2000	4000	RTmid
Tony's	0.55	0.58	0.51	0.57	0.45	0.44	0.54
Agora	0.54	0.63	0.59	0.66	0.49	0.46	0.63
Malvarosa	0.54	0.47	0.68	0.53	0.52	0.49	0.61
Trinquet	0.38	0.57	0.55	0.60	0.55	0.50	0.58
Pizzería	0.88	0.36	0.35	0.57	0.66	0.68	0.46
R.Mediter.	0.57	0.60	0.59	0.44	0.43	0.40	0.52



(a) (b)

*

(c) (d)

Fig. 2 PHOTOS INSIDE THE BARS: (A) TONY'S, (B) AGORA, (C) MALVAROSA, (D) TRINQUET

Fig. 2 shows some pictures of the environment in 4 of the premises. Here we expose the obtained results for pleasantness and nuisance in the different cafes and restaurants studied. A comparison of both measurements was made in order to analyze which of the premises is more pleasant or more annoying. We used the percentile 50 in order to evaluate (approximately) the mean value of each of these variables. P50 was used for the percentile 50 of

pleasantness (as the measure of the pleasantness shown during the 50% of the time recorded) and N50 was used for the percentile 50 of annoyance (as the measure of the nuisance shown during the 50% of the time recorded). Table II shows the mean values of P50 and N50. We have also studied the relationship established between them and RT_{mid}.

TABLE II RT_{MID}, P50 AND N50 VALUES FOR EACH PREMISE

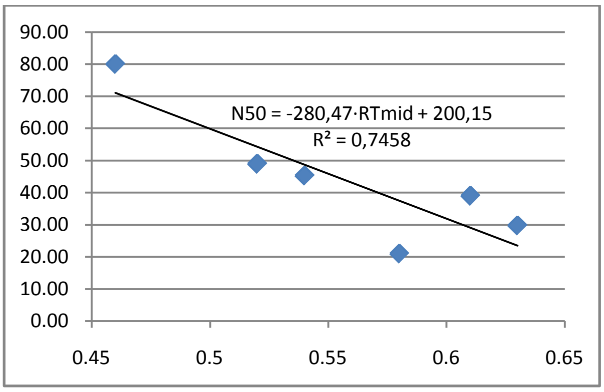
	RTmid	P50	N50
Tony's	0.54	0.0076	45.31
Agora	0.63	0.0208	29.79
Malvarosa	0.61	0.0110	38.99
Trinquet	0.58	0.0161	21.02
Pizzería	0.46	0.0031	80.05
R.Mediter.	0.52	0.0121	48.97

Pearson correlation coefficients set out in these relationships are: r (RT_{mid}-P50) = 0.8301 and r (RT_{mid}-N50)=-0.8636, so in this case we can deduce that the most reliable relationship for prediction is the nuisance produced inside the premises due to the acoustic conditions. Fig. 3 shows the graphics of the adjustment by the least-square method.

Subjective Assessment in One of the Premises

In order to assess the subjective response of the customers, a survey was carried out in Tony's cafeteria, one of the worst valuated in P50 parameters, to verify that our results are consistent with the point of view of people. The study has been performed using random sampling to 20 students in this premise.

The survey asked 10 questions, valuating in three points (nothing, little, much). The questions are shown in Table III and also the percentage of answers.



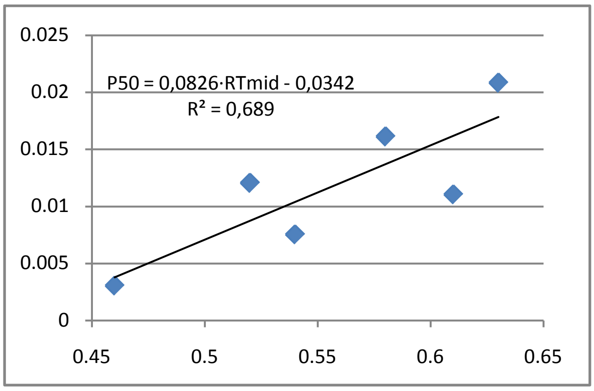


Fig. 3 GRAPHICS FOR THE ADJUSTMENT OF THE RELATIONSHIP BETWEEN NUISANCE/PLEASANTNESS AND RT_{MID} FOR THE 6 PREMISES

TABLE III SURVEY FOR SUBJECTIVE ASSESSMENT AT TONY'S

Question	% nothing	% little	% much
1) Is annoying the noise in the bar?	5	20	75
2) Do you have to shout to talk?	5	40	55
3) Do you know the risks of long term exposition to high level noise?	60	40	0
4) Are you used to the noise in the bar?	15	45	40
5) Do you usually go to noisy sites (disco, bar...)?	5	10	85
6) Would you go to another bar if they could assure you a lower noise level?	25	40	35
7) Do you think it is possible to reduce the noise levels in the bar?	10	50	40
8) Do you know any law on noise pollution?	65	30	5
9) Is this bar more annoying than others?	10	25	65
10) Do you think that noise exposition affects your usual way of life?	10	50	40

In this study, we have seen that most people agree (75%) on the nuisance obtained in Section III, although this value is not the highest of this study (but the highest in the University) and the comparative nuisance is perceived as one of the worst (65%). This fact affects the communication inside the bar. We have also seen that many people are not aware of the noise legislation (65%), neither the risks of long term noise exposition (60%), and usually go to noisy places (85%),

but even though they are little used to the environmental noise or nothing (60%).

Conclusions

In this paper we have studied the acoustic conditions of 6 premises by measuring T30 and doing the average for the determination of RT_{mid}. The premises are suitable for speech use, but in some of them the acoustic conditions have to be improved.

By applying the nuisance/pleasantness models by Zwicker to the recordings of the environmental sound inside the premises, we can make a relative comparison to assess the quality in each one of the premises.

Moreover, the study of the acoustic conditions in relation to the calculation of nuisance/pleasantness models has shown the effect of the acoustic conditions of the sites on the psychoacoustic nuisance produced inside the rooms.

This work has proved possible to establish quality criteria for public closed environments for catering and also the effect of the acoustic conditions on the nuisance model by Zwicker.

The survey has been a good source of information on the subjective assessment of the environment and has shown that the students are sensitive to acoustic conditions (in case of Tony's bar, the quantity of people thinking that this is the most annoying premise is 65%), but they think it is bearable. This fact is also in accord with the results of the model. To complete this study, a complete survey in all the premises would be necessary for checking the subjective response.

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